THE RELATION OF BIRD MIGRATION TO THE WEATHER.

BY WELLS W. COOKE.

The belief is quite general that there is a close connection between the weather and bird migration; that if the weather is not the cause of migration, it is at least the most important, indeed the governing, factor in determining the time of the bird's arrival, and particularly in causing the variations from year to year. The intimate relation supposed to exist between the weather and the bird's movements is thus promulgated by a very acute migration observer who wrote me: "I have collected such a large number of dates for our common birds that if you give me a good account of the weather conditions, I can give you the dates of arrival and movements of many species without going into the field." After an exhaustive study and comparison of bird arrivals with the accompanying weather, the results were found to be so utterly at variance with the above quoted opinion, that they were summarized as follows: "The weather encountered en route influences migration in a subordinate way, retarding or accelerating the birds' advance by only a few days and having slight relation to the date of arrival at the nesting site. Local weather conditions on the day of arrival at any given locality are minor factors in determining the appearance of a species at that place and time. The major factors in the problem are the weather conditions far to the southward, where the night's flight began, and the relation which that place and time bear to the average position of the bird under normal weather conditions."

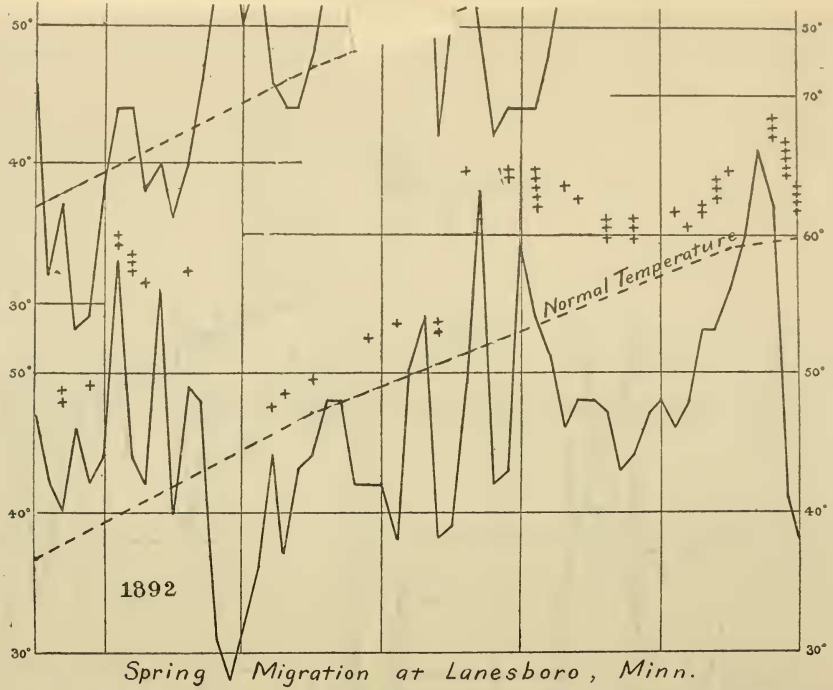
The above quotation is from an article that was written for the yearbook of the Department of Agriculture for 1910. In its necessarily condensed form, there was opportunity for nothing more than a mere statement of conclusions, without any of the data on which those conclusions were based. It seems advisable that a synopsis of the more important of these data should be published as a contribution to knowledge of the phenomena of bird migration.

For the solution of the proposed problem it is necessary to have the notes of a thoroughly reliable and competent observer, who is

constantly in the field so as to note the birds immediately on their arrival; it is also necessary that these observations be continued long enough to make possible the computation of reliable averages. A great advantage would be to have these records taken in a district free from mountains, valleys, or any other physical features that would tend to interfere with the free and uninterrupted northward movement of migration. The fulfilment of all these conditions was found in the work of Dr. J. C. Hvoslef at Lanesboro, Minnesota. An ardent student of bird life, a close observer with a good knowledge of birds, his profession as a physician with a large country practice, kept him daily in the field and made it probable, that few birds would escape his acute observation. Dr. Hvoslef contributed migration records for ten consecutive years, 1884–1893. At the same time notes were received from several towns in Iowa — notably Grinnell, Iowa City and Coralville — whose records are especially valuable as supplementary and corroborative evidence.

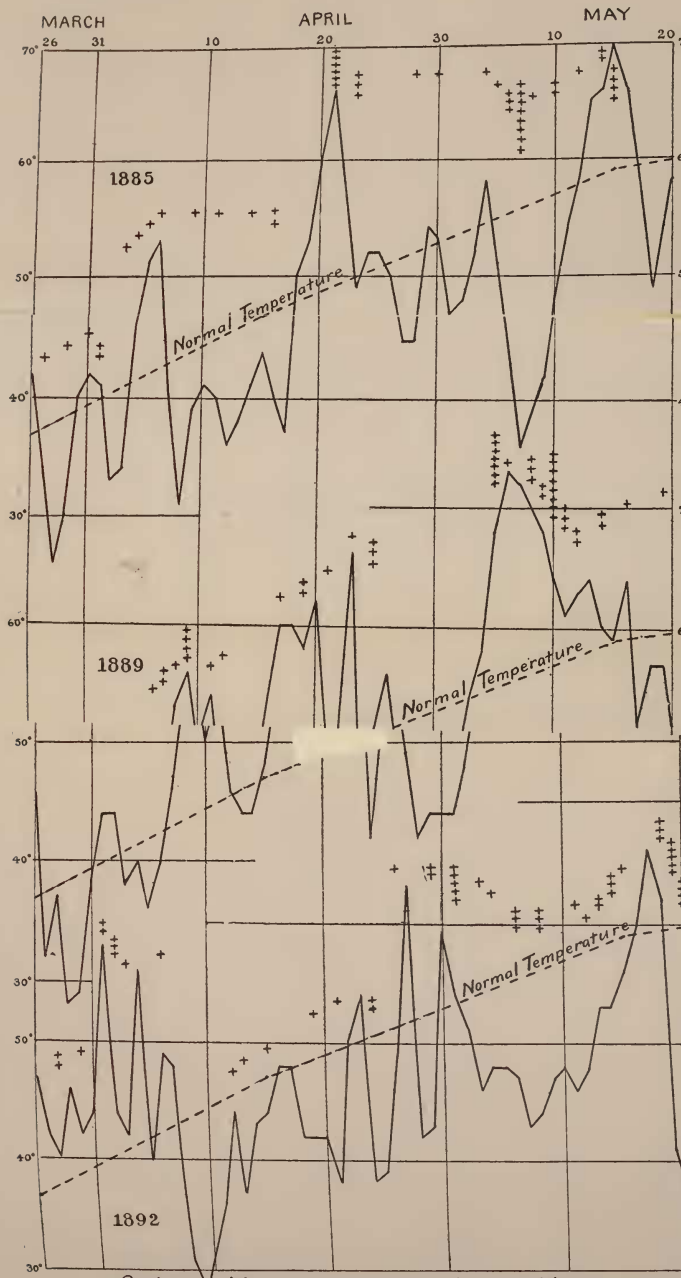
As is well known the weather comes usually in alternate cold and warm waves. If therefore the weather is the controlling factor in bird migration, then the progress of migration should be in waves corresponding to those of the weather, birds arriving freely when the temperature rises above normal and checking their advance when it falls below. While a sort of general correlation can be noted between the waves of weather and migration, the exceptions are many and striking. The accompanying chart gives the course of the weather and migration for three years at Lanesboro, Minnesota. The first year, 1885, shows two pronounced waves of bird arrival coinciding with two waves of decided warm weather; it also shows the biggest migration wave of the whole season coming at the coldest part of a sharp cold snap that sent the temperature far below normal. The second year, 1889, shows a close agreement between the larger waves of migration and the warmer waves of temperature. The third year, 1892, shows all the large bird movements as occurring not on account of the weather but in spite of it.

The bird wave of May 7, 1885, is particularly to be noted. On this day a storm of snow with a north wind forced the temperature below the freezing point, yet on the morning of May 7 "the woods and river bottoms seemed to be almost alive with small birds." Among these were the following seen for the first time:



Spring Migration at Lanesboro, Minn.

The heavy lines show fluctuations in temperature. The crosses show bird arrivals. Each cross represents the arrival of a species not previously noted that year.



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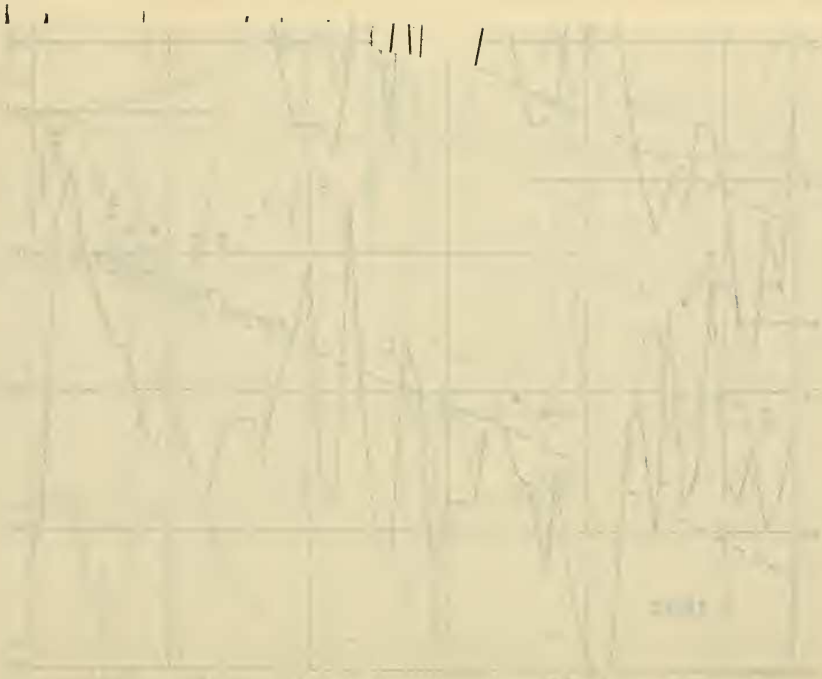

Catbird	average	date	of	arrival	May	6
Water-Thrush	"	"	"	"	"	6
Black-throated Green Warbler	"	"	"	"	"	7
Wilson's Warbler	"	"	"	"	"	8
Veery	"	"	"	"	"	8
Solitary Vireo	"	"	"	"	"	8
Nashville Warbler	"	"	"	"	"	9
Scarlet Tanager	"	"	"	"	"	10
Rose-breasted Grosbeak	"	"	"	"	"	10
Tennessee Warbler	"	"	"	"	"	11

A queer state of affairs is witnessed in the spring of 1892 when the temperature for a large part of the migration season was decidedly below the average. The birds arrived late but even then did not wait until the temperature had arisen to their normal.

Species.	Arrived later than the average.	Arrived at a temperature lower than the average.
	days.	degrees F.
Black and White Warbler	2	8
Lincoln's Sparrow	0	9
Ovenbird	2	13
Water-Thrush	0	9
Kingbird	5	10
Warbling Vireo	13	
Chestnut-sided Warbler	12	
Maryland Yellow-throat	7	6
Catbird	1	13
Yellow Warbler	10	
Wilson's Warbler	11	
Veery	6	4
Olive-backed Thrush	0	13
Red-eyed Vireo	9	
Indigo Bunting	13	
Scarlet Tanager	8	
Magnolia Warbler	11	
Tennessee Warbler	9	
Redstart	7	
Nighthawk	10	
Gray-cheeked Thrush	2	

As proof that birds are not dependent on any exact temperature for their time of migration, it can be stated that birds do not move north in the spring as soon as the temperature rises to the degree of warmth at which they ordinarily migrate. Thus the Baltimore Oriole arrives at Lanesboro, Minn., at an average temperature of about 55° F. but it does not make its appearance as soon as the temperature has risen to this point. The Oriole was not noted at Lanesboro before May 1 in any of the years from 1884 to 1893, though in 1884 a temperature of 55° F. was attained on April 25, in 1885 on April 20, and in the following years on April 9, April 8, April 26, April 9, April 11, April 13, April 1, and April 3. During the spring of 1886, the temperature from April 13 to April 23 averaged 65° F. but no Orioles appeared.

On the other hand, birds do not always wait for their average temperature before they migrate. In 1893 there had been no three consecutive days during the whole spring with as high a temperature as 55° F. when the Baltimore Oriole arrived at Lanesboro, and during the previous two weeks no temperature higher than 48° F. either at Lanesboro or in the country a hundred and fifty miles to the southward.

It thus appears that each species has a wide range of temperature at which it can migrate. In the case of early migrants this varies from 40° F. down to many degrees below freezing, while with the latest from about 40° F. to 70° F.

If the movements of migration are caused by the weather, then it should be that a late spring would retard the arrival, and that the birds would appear earlier in an unusually warm season. The facts do not seem to bear our this supposition. During the nine years, 1885–1893, at Lanesboro, the larger variation in the time of arrival occurred under the following conditions. In this table a 'warm' temperature is three or more degrees above the normal and a 'cold' an equal amount below; the intervening temperatures are called 'normal.'

Bird arrivals at Lanesboro, Minn. 1885–1893.

The birds came three or more days	No. of Instances.
early with a warm temperature	58
late " " cold "	60
on time with normal temperature	7
Arrivals agree with theory	125

The birds came three or more days	
early with a cold temperature	42
late " " warm "	41
early " " normal "	29
late " " " "	23
Arrivals do not agree with theory	135

The above figures show that in the case of the more pronounced variations, the arrival seems to have been hastened by warm weather or delayed by cold in only 125 instances out of 260, or only 48 percent.

The smaller variations show still less dependence of movement on warmth.

Bird arrivals at Lanesboro, Minn., 1885–1893.

	No. of Instances.
The birds came one or two days	
early with a warm temperature	47
late with a cold temperature	38
Arrivals agree with theory	85
The birds came one or two days	
early with a cold temperature	28
late with a warm temperature	43
early with normal temperature	18
late with normal temperature	23
The birds came on time with a cold temperature	15
" " " " " " " warm temperature	21
Arrivals do not agree with theory	148

Here is no evidence at all that the temperature has either stimulated or retarded bird migration.

A slight connection may be noted by comparing the total number of arrivals in warm and in cold weather. During the spring days of these nine years, when the temperature was above the normal, 243 arrivals of birds were noted, and when the temperature dropped below the normal, only 182 birds were recorded as arriving. This shows that whether or not the warm weather causes them to come earlier, they prefer on the average to advance when the weather is warmer than normal.

Birds prefer to migrate in spring during a rising temperature. This preference is strongly marked as will be seen by the following table based on the records of 1885–1893 at Lanesboro, Minnesota.

Year.	Number of instances that the mean temperature of the day of arrival was —		
	Three or more degrees warmer than that of the previous day.	Within two degrees or less of that of the previous day.	Three or more degrees colder than that of the previous day.
1885	20	10	18
1886	19	32	8
1887	37	6	11
1888	31	17	13
1889	28	13	17
1890	17	28	12
1891	41	14	5
1892	16	21	21
1893	25	19	10
Total	234	160	115

It will be noticed that the instances of arriving during or just after a rising temperature are just about twice as numerous as the opposite. Moreover it is to be remembered that out of these latter, there are 36 that occur on a pronounced cold day following just after a pronounced warm day, and it may easily be that many of these actually arrived on the warm wave of the day previous and were not detected until the following day.

The temperature of the day of arrival is on the average higher than the average temperature of the two days before the bird is noted. This is another way of saying that on the average birds move north when a rise of temperature occurs.

Species.	Average temperature of the day of arrival.	Average temperature of the two days previous to arrival.
	degrees F.	degrees F.
Lanesboro, Minnesota		
Robin	41	35
Fox Sparrow	46	42
Towhee	56	52
Brown Thrasher	57	56
Rose-breasted Grosbeak	59	56
Baltimore Oriole	58	55
Wilson Warbler	56	55
Magnolia Warbler	58	56
Scarlet Tanager	58	56
Grinnell, Iowa.		
Robin	35	28
Fox Sparrow	46	42
Towhee	49	43
Brown Thrasher	57	52
Rose-breasted Grosbeak	57	52
Ovenbird	55	51
Baltimore Oriole	55	53
Scarlet Tanager	56	55
Average	53	50

Let us next consider the very wide range of temperature under which birds migrate. The temperature at the time of the bird's arrival is easily ascertained, since it is probable that most night migrants begin their flight soon after nightfall, and accomplish the larger part of their journey before midnight, so that the temperature at ten o'clock in the evening would be close to the average temperature for that night's migration. This ten o'clock temperature can be calculated for any part of the Mississippi Valley from the permanent records of the United States Weather Bureau, and in the prosecution of this research, unlimited access was given by the Bureau to their original data.

To ascertain whether any relation exists between the arrival of the birds and temperature, eight common birds were selected, species so common, well known, and conspicuous, that they would

probably be seen immediately on arrival; these eight birds were also selected from early, medium, and late migrants, so as to have the test made during all parts of the migration period.

Species.	Average date of arrival.	10 P. M. temperature of the day before the bird was first seen.			
		Average.	Extremes	Extreme variat'ns.	Average variation.
Lanesboro, Minnesota, 1885–1890.		deg. F.	deg. F.	deg. F.	deg. F.
Robin	March 16	40	28–47	19	4
Fox Sparrow	April 4	44	33–58	25	7
Towhee	April 16	54	41–67	26	8
Brown Thrasher	April 24	57	38–69	31	10
Rose-breasted Grosbeak	May 4	59	36–67	31	8
Ovenbird	May 4	56	35–72	37	11
Baltimore Oriole	May 4	54	46–66	20	6
Scarlet Tanager	May 10	54	36–69	33	11
Average				28	8
Grinnell, Iowa, 1885–1890.					
Robin	March 6	32	24–41	17	5
Fox Sparrow	March 26	46	33–51	18	8
Towhee	March 21	46	34–51	17	5
Brown Thrasher	April 15	55	44–71	27	7
Rose-breasted Grosbeak	April 29	60	48–74	26	8
Ovenbird	April 29	55	48–67	19	5
Baltimore Oriole	April 29	56	49–71	22	5
Scarlet Tanager	May 2	60	52–71	19	7
Average				21	6
Average of both localities				24	7

The average variation in the time of arrival of these eight species is 3.8 days and the average variation in the temperature is 7° F. During the months of March, April, and May, the temperature in the Mississippi Valley rises about one degree for each two days, so that a variation of 7° F. would be equivalent to about fourteen days

variation in the time of migration. Thus the temperature under which the birds are migrating is about four times as variable as the day of arrival of the birds.

The above table representing the temperature at 10 P. M. of the night during which the birds arrived is probably the nearest approximation that can be obtained to the actual temperature at the time the birds arrived. Since the birds have undoubtedly flown many miles during the night, it might be that the temperature of the place where the evening flight started would have a controlling influence.

Species.	Average date of arrival at Lanesboro.	10 P. M. temperature, 150 miles south of Lanesboro, on the evening before the bird was first seen at Lanesboro.			
		Average.	Extremes.	Extreme variat'ns.	Average variation.
		deg. F.	deg. F.	deg. F.	deg. F.
Robin	March 16	45	34–57	23	7
Fox Sparrow	April 4	49	40–57	17	6
Towhee	April 16	58	47–73	26	9
Brown Thrasher	April 24	59	39–66	27	7
Rose-breasted Grosbeak	May 4	61	40–70	30	7
Ovenbird	May 4	58	40–71	31	10
Baltimore Oriole	May 4	57	49–64	15	4
Scarlet Tanager	May 10	58	40–76	36	7
Average				26	7

The average of these last two tables is probably the best statement obtainable of the actual temperature at which the birds migrated.

It is difficult to see how the mean temperature of the day when the bird was first noted could have had any great influence on its migratory movements of the previous night, but as these conditions under which we first see the bird are the ones we are most likely to associate with the bird's arrival, they have also been calculated.

Species.	Average date of arrival.	Mean temperature of the day the bird was first seen.			
		Average.	Extremes.	Extreme variation.	Average variation.
Lanesboro, Minnesota, 1885–1890.		deg. F.	deg. F.	deg. F.	deg. F.
Robin	March 16	41	31–52	21	7
Fox Sparrow	April 4	46	38–52	14	4
Towhee	April 16	56	38–66	18	8
Brown Thrasher	April 24	57	45–67	22	8
Rose-breasted Grosbeak	May 4	59	36–73	37	10
Ovenbird	May 4	55	36–73	37	10
Baltimore Oriole	May 4	58	44–73	29	9
Scarlet Tanager	May 10	58	36–69	33	9
Grinnell, Iowa. 1885–1890.				25	8
Robin	March 6	35	12–24	32	4
Fox Sparrow	March 26	46	38–56	18	6
Towhee	March 21	49	38–58	20	6
Brown Thrasher	April 15	57	45–67	22	6
Rose-breasted Grosbeak	April 29	57	49–71	22	6
Ovenbird	April 29	55	47–62	15	4
Baltimore Oriole	April 29	55	49–70	21	6
Scarlet Tanager	May 2	56	47–71	24	8
Average				22	6
Average of both localities				24	7

Other temperatures were also compared as follows:

Temperature.	Extreme variation.	Average variation.
	deg. F.	deg. F.
Mean temperature of the day before the bird was first seen	19	5
Average mean temperature of the two days before the bird was seen	15	5
Average mean temperature of the second and third days before the bird was seen	16	5
Mean temperature, 150 miles south of the place of observation, of the day before the bird was seen	21	6

The above temperatures probably include all that would influence the bird in the flight which brought it to the place of observation. A careful examination of these tables will convince anyone that these temperatures with their great variations could not have been the cause of the migration. A bird that arrives with an average temperature of 50° F. may appear one year when the temperature is below 40° and is just as likely to be seen for the first time the next year with a temperature far above 60°. Even omitting the extreme variations, yet the average variations are far more variable than the movements of the birds and demonstrate that temperature alone does not cause the birds to move northward.

Conversely these figures show that no one of these birds is restricted to any single temperature for the performing of its migration, but that each one can and does migrate with a wide range of temperature.

It is interesting to note in passing, the wide differences between the average temperature of the day of arrival, and the average of the temperatures of the days of arrival. Thus the average date of arrival of the Robin for the years 1885–1890 was at Lanesboro, Minn., March 16, and the average temperature of March 16 at Lanesboro is 31° F. But the average of the temperatures of the days during 1885–1890 on which the Robin was first seen at Lanesboro was 41° F. This indicates that the Robin had varied its arrival both before and after March 16 so as to arrive on those days that were warmer than the average. An extreme difference of 10° was found in the case of the Robin which is an early migrant and often encounters severe storms. With birds like the Brown Thrasher which move about the middle of the season these differences are only about half as great, while in the case of late migrants like the Baltimore Oriole and the Scarlet Tanager these differences disappear, since in the latter part of the season few storms are severe enough to interfere seriously with migration.

In addition to all the local temperatures at the time of arrival, it is possible that the total heat for the previous month or the total heat of the whole spring might be a determining factor. All of these different temperatures were examined and to show how they work out in detail, all these temperatures are given for a single species; the bird selected is the Baltimore Oriole because that

Relation between the Weather and the Arrival of the Baltimore Oriole at Lanesboro, Minnesota.

Year	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893		Average Percent of Variation
Date of arrival	May 6	May 6	May 5	May 1	May 6	May 5	May 2	May 3	May 3	May 6	May 4	
Total degrees of heat from January 1 to day of arrival	3507	3132	3833	3332	2840	3901	3576	3716	3594	3037	3427	31
Total degrees of heat from March 1 to day of arrival	2644	2548	2814	2513	2283	3060	2377	2405	2432	2459	2562	30
Total heat at Dubuque from March to day before arrival at Lanesboro	2707	2598	2721	2522	2528	2944	2417	2507	2457	2564	2597	20
Total heat at Davenport from March 1 to day before arrival at Lanesboro	2901	2805	2815	2614	2686	3014	2570	2565	2588	2691	2615	15
Average temperature of April at Lanesboro	46	46	52	48	44	49	50	49	44	43	47	19
Average temperature of April at Dubuque	48	47	51	51	48	50	51	51	46	45	49	12
Average temperature of April at Davenport	50	49	52	52	50	51	53	52	47	47	50	12
Mean temperature at Lanesboro of the day the species was first noted	57	53	59	73	50	68	54	50	46	50	56	48
Mean temperature at Lanesboro of the day before arrival	58	51	57	67	51	58	48	51	51	48	54	35
10 p. m. temperature at Lanesboro of the day before arrival		46	56	65	52	66	54				56	36
Mean temperature at Dubuque of the day before the bird is noted at Lanesboro	61	55	59	66	54	59	50	51	58	44	56	40
Mean temperature at Davenport of the day before the bird is noted at Lanesboro	63	56	60	65	56	60	50	50	62	44	57	37
10 p. m. temperature at Davenport of the day before the bird is noted at Lanesboro		49	56	64	59	67	59				59	31

has the smallest variation in its time of arrival of all the birds that were recorded at Lanesboro.

In the matter of the total amount of heat received in the spring the variations are 30 percent whether estimated from the first of January or from the first of March, moreover the largest variations from 2283° in 1888 to 3060° in 1889 occur with but a single day difference in date of arrival. The same result is obtained if the date of appearance is compared with the total heat received in the vicinity of Dubuque, eighty miles south of Lanesboro, or at Davenport, a hundred and fifty miles farther south, though the percentage variations are not so great, that at Davenport being only 15 percent.

Parenthetically it may be remarked that the temperatures during the winter and previous to March 1 have seemingly no effect on plant or animal growth and it is the degrees of heat after March 1 that determine the advance of the season. This was strikingly shown at Washington, D. C., the spring of 1912, when after a winter of unusual severity in January and February, the growth of plants became fully up to normal as soon as the heat after March 1 had risen to its normal and long before the total heat counted from January 1 had reached the average. The bird arrivals averaged earlier than usual notwithstanding the cold winter.

The variations in the time of the arrival of the bird from year to year do not agree with the variation of the season. The spring of 1889 is the warmest, March and April together, at all three places; indeed that spring is one of the warmest the Mississippi Valley has ever known, but the Oriole does not arrive so early this year as the average of the ten years. But little relation can be traced between the changes in temperatures and the changes from year to year in the time of arrival. It is true that in 1893, when the Oriole arrived at its latest date — May 6 — the temperature is the coldest at all three places, and in 1887 when the date of arrival is the earliest — May 1 — the temperature is also the highest at all three places. But here the agreement ends, for the Oriole also arrives on May 6 in the years 1884, 1885, and 1888, that are both cold and warm years and on May 2 in 1890 that is among the colder years.

During spring migration the direction of the wind seems to have